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Cables :: "Stomata." | Phone :: 0365

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LIVESTOCK IMPROVEMENT

The opening words of Dr. Nichols' book* define the task undertaken :

"Formal genetics does not always provide a satisfactory or convenient approach to an understanding of the principles involved in questions of livestock improvement and selection. The breeder finds it too remote at many stages from practical applications and bearings; for the agricultural and veterinary student it usually follows too detached a route. The approach used here represents an attempt to outline the principles and to indicate how the genetic and environmental concepts are interwoven in the idea of stock improvement".

The great advances made on the development of specialized types and breeds of temperate zone livestock during the last two centuries were achieved largely without the aid of the science of genetics, which evolved almost entirely in the present century. In retrospect the cost of this obligatory empirical development can be read in the history of breeders and of their stock. The situation in tropical livestock breeding today is closely similar to that existing in Britain two hundred years ago with the exception that a body of genetical information now exists which can save the tropical stock-breeder much costly experimentation.

The author begins with the constructive breeder or improver who, having developed a conception of what constitutes his "ideal tye", proceeds by some form of selection to improve his stock towards this objective. Attention is then drawn to the need of "environmental control", in other words to good husbandry. It is obvious that no true assessment of a breeding policy can be made unless the system of management and feeding is at a level high enough to allow expression of the improvement achieved. Emphasis is rightly placed on the need of objective measurements (growth rates, carcass tests, milk and lactation records, fecundity and survival studies &c.) to assist the evaluation of type.

While admitting that livestock shows and show standards are valuable from a number of standpoints, Dr. Nichols considers that there are certain objectionable features: (1) they frequently overemphasize appearance on points of conformation which are attainable only under systems of feeding and management and which cannot be attained

*Nichols, J. E.—Livestock Improvement in relation to Heredity and Environment. Oliver and Boyd Ltd., London, pp. 207, 10s. 6d.

economically under conditions of normal commercial management; (2) they tend to be dominated by shades of opinion held, for a period, by a relatively small and exclusive group of breeders; (3) they frequently overlook the importance of physiological function and often emphasize fancy points which, although complicating the selection policy, do not add to productivity. It is rightly suggested that the score card method of judging, although imperfect, is one method of combating these drawbacks.

It is pointed out that the introduction of animals from regions where the standards of husbandry are high into areas where agriculture is at a primitive level has not always been successful in the grading-up of local cattle. In such areas animals are frequently found who shew superior performance in spite of inferior husbandry. It is suggested that the use of these animals in selection programmes may yield better results, ultimately, by not disturbing the existing balance between hereditary constitution and primitive methods of husbandry.

When exotic animals are introduced to improve indigenous stock there is a tendency for simultaneous improvements to occur in the methods of husbandry. Thus it is difficult to assess the extent to which the introduced stock was responsible for any improvement attained. Dr. Nichols suggests that there are cases where improved husbandry alone is necessary and that grading-up towards a pure bred stock may be disadvantageous.

Consideration is given to differences between breeds and between closely related species in their physiological needs and functions and to the extent to which nutrition may modify inherited characteristics. Thus the condition of poultry known as slipped-tendon (perosis) is a character of genetic basis which is prevented from developing by a relatively high intake of manganese. The White Leghorn is less susceptible to perosis than most other breeds of chickens and has a lower manganese requirement. In addition this breed requires less vitamin B_1 than other breeds. Information about the influence of the plane of nutrition upon body form is also given and evidence of the great influence which nutrition can exercise upon the expression of genetic characteristics is presented. It is regrettable that, owing to the nature of his task, Dr. Nichols was unable to devote space to those recent experiments from various laboratories which shew how nutrition operating through the endocrine system produces these modifications. From the standpoint of the tropical stockbreeder the profound effects of planes of nutrition in modifying type are especially important since wide seasonal fluctuations in food supplies occur in many parts of the tropics.

Of particular interest to tropical breeders is the information given about differences between breeds of cattle in their ability to withstand high environmental temperatures and of the extent to which this adaptability is inherited by cross-bred cattle. Attention is also given to congenital porphyrinuria ("pink tooth") of African cattle shewing that susceptibility to the condition is inherited as a recessive. Under intense sunlight skin lesions develop owing to photosensitization and death follows after a short interval. Parent stocks in Britain and Holland, where irradiation intensity is so much less, do not develop these fatal lesions.

While infertility and sterility of tropical cattle are frequently stressed by some writers, it seems doubtful whether the problem is more severe than in temperate zone cattle. Dr. Nichols records that in Great Britain the average number of lactations of dairy cows averages between three and four with twenty per cent. of the wastage arising from sterility. In Denmark, with an average of four lactations, eighty per cent. of the wastage is caused by sterility. A forty-five year study of the Norwegian Agricultural College herds shewed that about fifty per cent. of all the cows had up to three pregnancies and that infertility was the cause of forty per cent. of culling. Since this high wastage compels the retention of over fifty per cent. of the heifer calves the opportunities for selection to improve herds is seriously limited.

Dr. Nichols discusses in detail selection systems of breed construction and indicates the degree of success likely to be attained by different practices. It is impossible to review here all the aspects of the problem although the following two methods of breed improvement are of particular interest. The Lush method is based on the division of the breed into local groups each following a common linebreeding policy with outcrosses from nearby groups as required. Each group should have three to five males so that a course midway between too high in-breeding with too few males and too slow progress towards group uniformity can be avoided. The Hagedoorn method proposes a few nucleus groups selected as free as possible from undesirable recessives and lethals and rigorously protected against their introduction later. The nucleus would contain only a few superior progeny-tested males and the sires used throughout the breed would be exclusively the sons, or sons and grandsons, of these animals.

The Lush method appears to be favoured by Dr. Nichols in that it allows for progeny tests to be carried out in the area where the stock will be called upon to demonstrate their productive merit. The Hagedoorn method suffers from the weakness that it assumes the nucleus stock to contain a sample of gene material sufficient to accommodate changes in environment. Certainly the Lush method would be more attractive in the islands of the West Indies, at least, where wide differences in environment exist.

Too few books are published which succeed in relating the present state of scientific knowledge to concurrent practical problems. Dr. Nichols' book takes its place in this category and will be a valuable guide to those whose task is the improvement of domestic animals.

JOHN DUCKWORTH

ENSILAGE INVESTIGATIONS WITH TROPICAL FORAGES

BY

D. D. PATERSON

(*Professor of Agriculture, Department of Agriculture, Imperial College of Tropical Agriculture*)

The declared policy for agricultural rehabilitation in many of the West Indian islands is the establishment of an organised system of permanent mixed farming in place of existing systems of land usage which are commonly forms of shifting agriculture, bush fallowing, or of mono-crop cultivation. Any widespread change over to mixed farming necessitates as a pre-requisite, development and expansion in animal husbandry and in particular substantial reform in the number, class, and quality of livestock. Stock foods for both maintenance and production rations will largely be in the form of home-grown feeding stuffs; and forage crops, grasses, and legumes at once assume greater importance in the general economy of the mixed farm. A regular supply of roughage and of nutritious forage or home grown foods must be ensured throughout the year. During the rainy season, which in much of the Caribbean area may be said to continue for some nine months, the cultivation of appropriate species of perennial tropical fodder grasses will provide a liberal and steady yield of nutritious green herbage for soiling or perhaps grazing; but for the remaining two to three months of dry weather, some bulk storage of conserved forage will have to be provided, if the quality of the rations and the productive output of the livestock are to be maintained. In the insular tropics an obvious source of supply of conserved fodder will be the surplus production of green herbage from the cultivated grass fields at the height of the wet season (9). High humidity at that season of the year rules out successful or economical hay-making by natural means, and artificial drying, even where the equipment is available, tends to be expensive and has the added disadvantage that after drying, the grass may go mouldy in store before it is required for stock food. Storage in the form of silage would thus appear to be the best solution, and the results of the last three years' investigations at the Imperial College of Tropical Agriculture on the ensiling of tropical forages during the wet season for feeding in the form of silage in the dry weather may be of interest to stock farmers.

Ensilage

Recent researches into the conservation of fodder crops have stimulated interest in ensilage as a method of conserving green forage and have provided a clear-cut picture of the various chemical and other changes taking place in the silo under a given set of conditions. The manufacture of good silage is no longer a case of trial and error, for the exact conditions requisite for the production of any given grade of silage are known, and in the case of failure, the contributing causes can be traced to source, and a repetition of that failure avoided. Briefly, the key to success is the effective restriction of the amount of air in the filled silo and the rapid acidification of the whole mass to prevent undesirable fermentations leading to butyric acid formation (5). A pH of 4.5 or less should be attained within the first week from filling the silo, and depending on the particular type of silage ultimately wanted, the temperature reached in the same period in the centre of the silo may be anything from 72°-120° F. Higher temperatures above say 130°F are generally considered undesirable as they cause the breakdown and loss of the valuable carotene content of the green herbage. The following qualities or types of finished product according to the particular fermentation process going on inside the silo are generally recognised :—

(i) Greenish-brown "fruity" silage typical of the cold fermentation process with temperatures not exceeding 85°F and with a high degree of compaction and exclusion of air; usually made from young and succulent forage.

(ii) Acid light-brown silage as a result of low temperature fermentation at levels of from 86-100°F; generally made from more mature herbage which may even be allowed to wilt before filling into the silo.

(iii) Sweet dark-brown silage produced by the warm fermentation process with temperatures rising to 115°-120°F.

(iv) Sour; rancid; musty; mouldy silage all representing spoiled silage resulting from bad raw material or poor processing.

Experiment Silos

For the initial experiments, in order to provide controlled conditions for the accurate comparison of different ensilage processes with various forages, it was decided to construct a battery of concrete tower silos in miniature, and the first four of these were erected on the College Farm in June 1942; later, four more were added making eight experimental units in all. Each small silo was 6 feet high by 3 feet internal diameter and was constructed out of two reinforced concrete culverts up-ended one on top of the other, with the bottom end of the lower one set in a special concrete base fitted with a drain pipe and small well for the collection of any effluent expressed from the herbage (Fig. 1 (a) & (b)).

A device for taking the temperature of the ensiled mass about the centre of the silo was fitted in the form of a length of $\frac{3}{8}$ inch metal tube inserted through a sliding orifice half way down the outer face of each silo in such a way that the tube could be forced into the centre of the silo whenever temperature readings were required. Each silo

had a capacity of approximately ½ ton of silage which is reckoned to be about the smallest bulk of material that will ensure controlled conditions of manufacture.

Some twenty forages or mixtures were tested in these experiment silos, a period of not less than four weeks being allowed in each experiment for the completion of the ensiling process. The results are summarisd in Table I, of which the following would appear to be the important facts:—

All the silage produced was of the acid yellow to brown type resulting from the low temperature fermentation process with temperatures ranging from 85 to 96°F.

The degree and rate of acidification was on the whole satisfactory being with a few exceptions well below a pH of 5.0. The surface wastage due to exposure to the air was not excessive, a top layer of from 1 inch to 6 inches deep of mouldy silage being all that was unfit for feeding to stock.

Chaffing, particularly with the small experiment silos, has much to recommend it as it effectively reduces surface waste, ensures good mixing and compaction, and improves the ease of handling and the digestibility of the silage.

The addition of molasses at the rate of 2 gallons per ton of green herbage tended in general to improve the quality of the silage and to minimise wastage; its addition was not essential to the production of good silage from cultivated grasses, but where a legume grass mixture is to be ensiled, the application of molasses up to four gallons per ton is beneficial; and for the ensiling of pure legume forage up to six gallons of molasses per ton is recommended.

The ensiling of green herbage with less than 20 per cent. dry matter content is inadvisable; with very succulent forage a preliminary process of wilting to decrease the water content of the herbage before filling the silo may be beneficial; the ensiling of herbage wet with rain or dew is not good practice as it is liable to produce a layer of wet imperfectly conserved silage at the bottom of the silo while increasing the nutrient losses by fermentation and leaching.

There is no easy road to success; proper attention to mixing, filling, molassing, covering and weighting each day's filling is essential to the production of good silage without undue wastage. The ensiling of a protein rich forage such as a legume-grass mixture gives a better return for labour and other costs of ensiling than the use of poor roughage. Provided the requisite precautions are taken in filling the silo, satisfactory silage can be made with any of the forages listed in Table I, and the losses through fermentation or surface wastage should not exceed 10 to 15 per cent. of the fresh green material or of the nutrient constituents it contains.

Bulk Silage

In addition to the silage made in the battery of concrete experiment silos, two bulk lots of 3½ to 4 tons each of Guatemala grass herbage were ensiled in improvised silos—one in a pit and the second in a bamboo clamp. In both cases the loss of nutrients through fermentation and surface wastage was excessive amounting to over 75 per cent. of the total material in the case of the bamboo clamp, in which effective air exclusion proved impossible. The pit silage was better with some two thirds of the original weight of material recovered in the form of good acid brown low-temperature silage. It seems probable that the 33 per cent. loss through fermentation, drainage and surface or edge wastage could be materially reduced in the case of the pit silo by taking certain additional precautions. Of these the use of a canvas or hessian cover to exclude air and the prevention of serious loss of the effluent through the drainage outlet or by percolation through the porous floor of the pit appear to be most important. Fuller discussion of the possibilities of pit silos is appended in connexion with the succeeding year's investigation in which they were used to provide bulk silage for simple feeding trials with cattle.

Pit Silos

The next series of investigations was the manufacture of 4 to 5 ton lots of silage in pits for the purpose of testing the efficacy of this form of silo as a medium for ensiling various tropical forages. Three pits were dug in a bank clear of subsoil water or surface drainage, each pit being approximately 15 feet long by 4 feet deep by 8 feet wide at the surface and 6 feet wide at the bottom (Fig. 2 (a) & (b)). This meant that the side walls had a 1 in 4 slope inwards which ensures better compaction of the ensiled mass, and with the same object in view the walls of the pit were "cemented" with a mud clay plaster which sun dried to a surface sufficiently smooth to prevent side-drag as the silage settled. A drainage outlet was installed in only one of the three pits as it was thought that the gravelly sandy loam forming the floor of the other two was sufficiently permeable to obviate any special drainage facilities. The three pits made it possible to ensile more or less concurrently three different types of forage in all, the raw material in every case being chaffed and treated with molasses during the process of filling. A check on the investigations in the form of a control silo was arranged for by filling three of the small concrete experiment silos with the same green forage as went into the three pits. The pit silos were opened in rotation some 4 to 5 months after filling and the silage was used for feeding to livestock at the height of the dry season. A synopsis of results is appended on Table II.

Comments on Table II

In all three pits, after the first 2 inches to 3 inches spoiled material had been removed from the surface, the silage was for the first two feet from the top in the nature of good quality light-brown silage gradually changing to green fruity wetter and more succulent material towards the bottom of the pit. In all cases the loss by surface spoilage for an improvised silo was satisfactorily small ranging between some 5 to 9 per cent. of the total

Table I

Forage	Fresh Material			Silage					Grade of Silage
	Processing	Dry matter %	Crude protein % of dry matter	Max. temp. °F.	pH	Dry matter %	Crude protein % of dry matter	Loss in weight %	
A. Young grass silage									
(i) Guatemala grass (*Tripsacum laxum*) 6 weeks old succulent herbage	Unchaffed ..	22.2	7.69	88	4.67	19.9	7.38	—	Light brown acid silage as from low temperature fermentation process
do. do.	Unchaffed molasses at 2 gall. per ton	22.2	7.69	88	4.30	21.8	6.83	—	do. do.
do. do.	Chaffed ..	22.2	7.69	88	4.63	21.4	6.46	—	do. do.
do. do.	Chaffed : molasses at 2 gall. per ton	22.2	7.69	90	4.40	21.7	7.06	—	do. do.
(ii) Uba cane (*Saccharum sinense* var. *Uba*)—Old herbage 4-6 months.	Chaffed : molasses at 2 gall. per ton	21.2	5.84	90	3.58	19.07	5.32	.98	Acid yellow brown silage
(iii) Para grass (*Brachiaria mutica*)—old forage, stemmy rather than leafy	do.	21.2	5.08	95	4.33	26.59	5.84	8.03	Light brown acid to sweet silage
(iv) Guatemala grass 6 weeks old, wilted	do.	14.25	8.82	87.5	3.65	15.01	9.28	9.54	Greenish yellow rather wet poor silage
(v) Elephant grass (*Pennisetum purpureum*)—4-6 weeks old	do.	24.68	5.67	90	4.40	22.17	5.84	12.16	Pleasant smelling acid brown silage
B. Legume-grass mixture									
(i) Woolly pyrol (*Phaseolus mungo*)—8 weeks old in flower and Guatemala grass 7 weeks old ; 1 : 3 mixture	Chaffed ; molasses at 2 gall. per ton	21.02	9.43	90.5	4.39	21.81	11.25	5.05	Uniform acid light brown silage
(ii) Woolly pyrol—8 weeks old in flower and Guatemala grass 7 weeks old ; 1 : 1 mixture	do.	21.18	12.84	90	4.52	20.54	11.97	1.75	Greenish yellow fruity silage
(iii) Woolly pyrol—8 weeks old in flower and Guatemala grass 7 week old ; 3 : 1 mixture	do.	18.22	17.39	91.4	5.02	18.39	14.93	+ 2.32	Acid light brown silage
C. Pure legume silage									
(i) Woolly pyrol—10 weeks old in flower	Chaffed : no molasses	20.57	18.16	88	5.14	16.86	17.79	4.77	Brown strong smelling silage
do. do.	Chaffed : molasses at 2 gall. per ton	20.57	18.16	90	4.26	19.99	17.33	12.57	Acid dark brown silage
do. do.	Chaffed : molasses at 4 gall. per ton	20.57	18.16	90	4.33	20.46	16.64	7.05	Acid yellow brown silage
do. do.	Chaffed : molasses at 6 gall. per ton	20.57	18.16	96	4.03	21.19	17.24	13.98	Acid light yellow silage

Table II

Forage	Processing	Green Forage		Silage				Loss ; % of total materials ensiled
		Dry matter %	Crude protein ; % of dry matter	Max. temp. °F.	pH	Dry matter %	Crude protein ; % of dry matter	
Pit I Para grass herbage (*Brachiaria mutica*) 7 weeks old with some 20 % other grass and weed admixture : wet and succulent.	Wilted overnight ; chaffed ; molasses added at rate of 3 gallons molasses plus one gallon water per ton of herbage	18.61	10.44	104	5.09	18.15	8.51	38.80 34.24 Fermentation 4.56 surface spoilage
Pit II Woolly pyrol (*Phaseolus mungo*) 8 weeks old just beginning to flower and 8 weeks old sugar cane forage (*Saccharum officinarum*) 3 : 10 mixture	Chaffed ; mixed ; molasses at rate of 4½ gallons molasses plus 1½ gallons water per ton of forage	24.06	11.64	102.2	4.87	21.26	9.81	23.57 14.70 Fermentation 8.87 surface spoilag
Pit III Sugar cane (*Saccharum officinarum* var. *B.H.* 10/12) old forage 4-6 months growth, some 6′ tall and beginning to cane	Chaffed : molasses at rate of 2½ gallons molasses plus 1 gallon water per ton of herbage	26.73	4.29	99.5	3.82	23.73	4.88	29.82 23.41 Fermentation 6.41 surface spoilage

weight of raw material ensiled. The losses through fermentation and drainage were not excessive except possibly in the case of Pit I where it exceeded one third of the whole material. It should be understood that some loss in total weight of dry matter as a result of the various fermentation and other changes occurring inside the silo is inevitable. For even a large concrete tower silo a loss on this count in dry matter of 10 to 12 per cent. of the material ensiled would not be untoward, and for pit silage the recorded losses for Pits II & III of 14.70 and 23.41 per cent. respectively as a result of the process of ensilage are not unduly high. Controlled experiments in Sweden (5) have shown that in any process of ensilage losses of organic matter in the nature of 11 per cent. due to fermentation and respiration, 1 per cent. in the drainage and 3 per cent. due to spoilage must be expected. Some such percentage losses are inevitable although the alteration of the method of manufacture may effectively reduce the total loss as well as alter the proportion attributed to each factor.

The relatively high fermentation losses in Pit I are attributed to ensiling, under improvised conditions, succulent wet green material with a low dry matter content in a pit in which free drainage of the effluent was encouraged.

Feeding the Silage

The pits were opened in the middle of the dry season some four to five months after filling, and the silage was used as a maintenance ration for cattle. The extraction of the silage was effected by digging away one end wall of each pit so as to expose a vertical face in cross-section of the silage and give access for a hand trolley on which the silage could be loaded. Each day's requirements of silage was cut off with a hay knife and represented a vertical slice about one foot thick, which was loaded on to the trolley and carted off to the cattle pens for feeding forthwith. The exposed vertical face of silage was closed in by a board shaped to the exact cross section of the pit, and a sheet of galvanized iron placed across the top effectively prevented any rain from penetrating into the silage (Fig. 3 (a) & (b)).

In this way, the silage was extracted from each pit over a period of some 15 to 20 days without any surface spoilage due to temporary exposure of the open end.

The silage was fed to batches of four cattle ranging from pure-bred Zebu heifers to 3/4 bred Holstein and Zebu stud bulls. No attempt at comprehensive digestibility trials was made, but the general reaction of the livestock to this new form of ration was noted. One week's transition period to allow a gradual change over from the usual rations of grass forage plus concentrate meal to a 100 per cent. silage ration was allowed ; and after this transition week the stock was fed to appetite on silage alone for a period of 15 days. The cattle took to the silage readily and more than maintained their weight and general condition or bloom over the fifteen-day experiment period. They remained in good health entirely free from

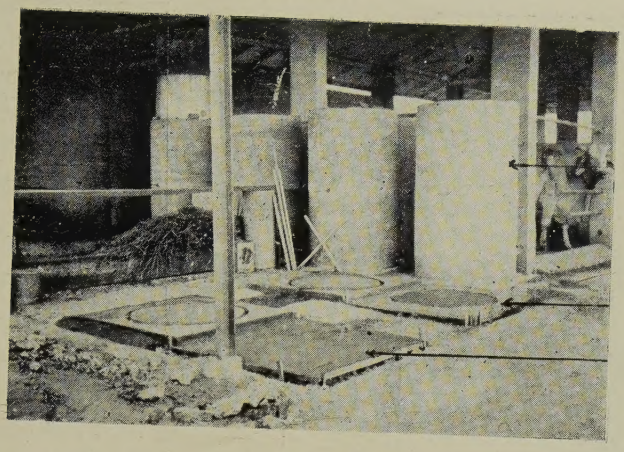
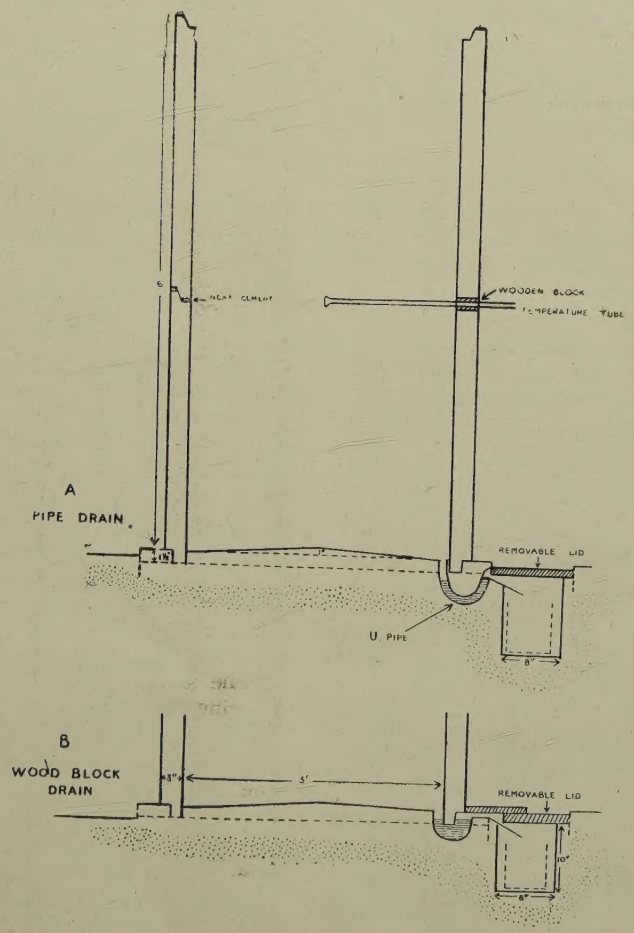


FIG. 1 (a)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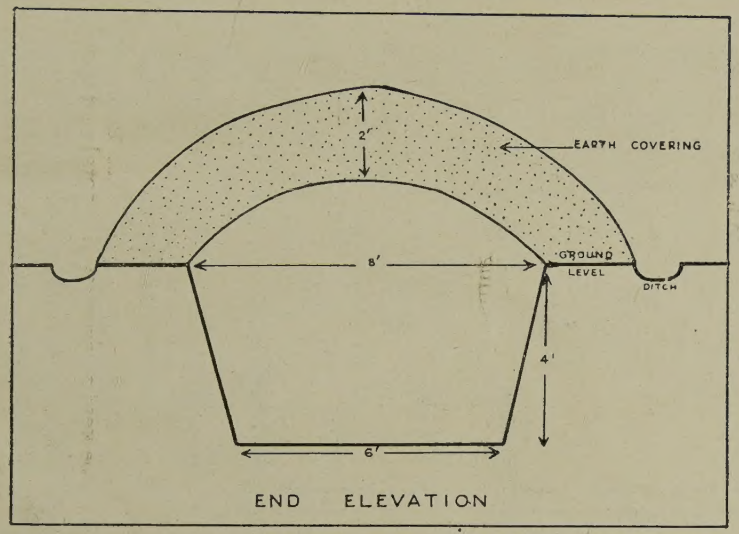

FIG. 2 (a)

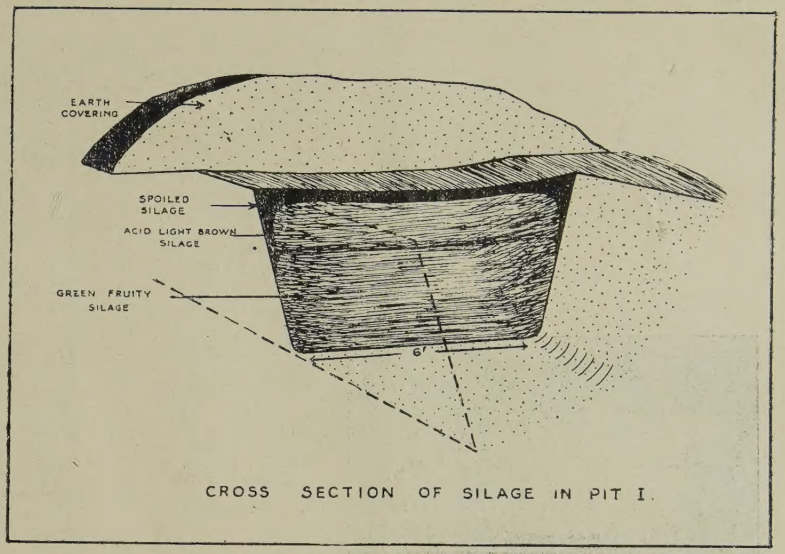

FIG. 3 (a)

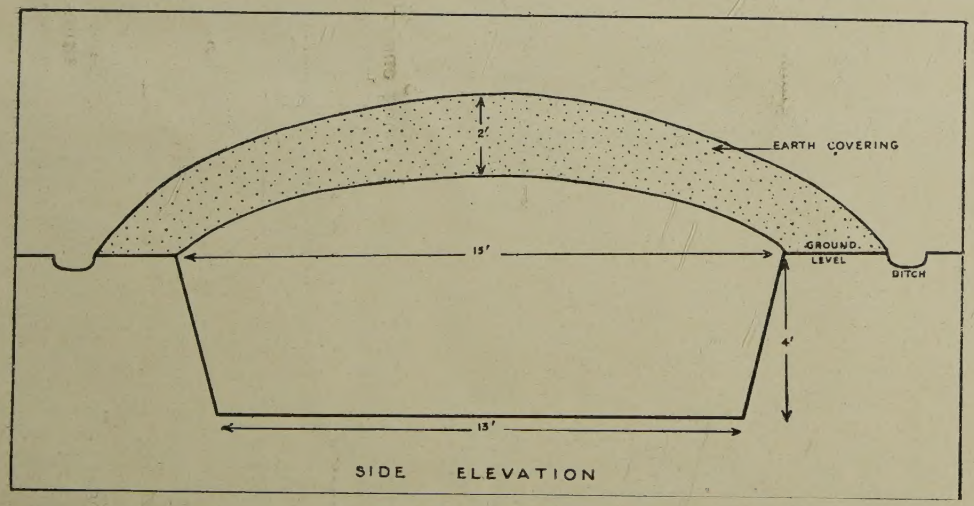

FIG. 2 (b)

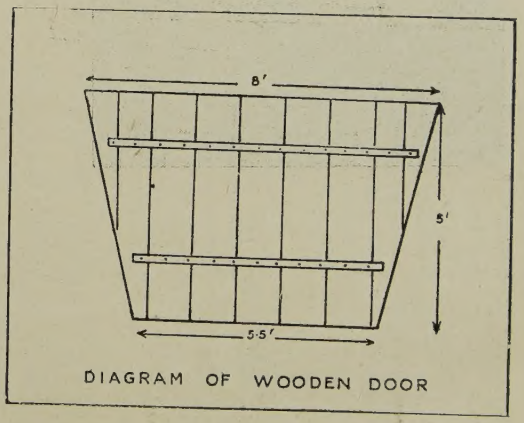

FIG. 3 (b)

scouring or other signs of digestive upset and consumed on an average for a 700 to 800 lb. animal, some 70 lb. of silage per day in the form of Para grass or legume-sugar-cane forage mixture from Pits I and II respectively. The same batch of animals fed subsequently on the silage from Pit III composed of semi-mature sugar cane herbage consumed only 50 to 60 lb. per head and showed signs of decreasing appetite. The nutritive quality of this silage from Pit III was definitely poorer than that from the other two pits, and its general palatability was further spoiled by the presence of sections of hard cane round which some butyric acid fermentation had occurred and which the animals refused to consume.

It is interesting to note that the cattle fed on the Para grass silage from Pit I took avidly to salt licks supplied to them in the second week of the fifteen day feeding trial with silage. They were evidently short of mineral salts as a result of a ration limited to silage alone. It is known that during ensilage there may be a material loss of inorganic salts leached out in the effluent draining out of the silo, and this is evidently what had happened in the case of the Para grass silage where not only was the fresh herbage very succulent and surface wet in character, but free drainage from the bottom of Pit I was also provided. Where the mineral content of silage is not definitely known the provision of salt licks when silage is being fed might be a useful precaution to adopt.

The manufacture of silage is really justifiable only when reasonably nutritious young forage is available for ensiling in the first instance, and the admixture of even 20 to 25 per cent. of leguminous forage in ensiling grass herbage is distinctly advantageous. No long term grass-legume association has yet proved possible for tropical conditions, and the inclusion of a legume in the silage would therefore imply the growing of a small area of a legume forage crop, such as woolly pyrol, for the purpose. This is an expense that many farmers might be unwilling to incur and, as an alternative, it was suggested that the leguminous portion of the silage mixture might be provided in the form of young shoots of *Gliricidia sepium* which is often planted as a quick growing hedge or wind break. This was actually carried out in two of the experiment silos, a 25 : 75 and 50 : 50 Gliricidia-Guatemala grass mixture being ensiled successfully by a process involving both chaffing and molassing of the green forage. The resultant silage was of the usual acid brown classs as produced by the low temperature fermentation process, but it had a distinctly strong and unusual odour due apparently to coumarin produced from the Gliricidia foliage. The cattle ate the silage readily enough, but its odour was so strong that pending further investigations its use for dairy cattle could not be recommended. Actually, the limiting factor in this particular legume-grass mixture would appear to be the cost of obtaining the necessary yield of young Gliricidia shoots for the manufacture of bulk silage on a farm scale.

Discussion

Certain clear cut facts may be deduced from these preliminary investigations on the ensiling of tropical forages. These features might be summarised as follows :—

(i) The manufacture of silage by the low temperature fermentation process from tropical forage in the middle of the rainy season is practicable.

(ii) Losses by spoilage and fermentation need not be excessive provided the requisite precautions are taken in the process of filling the silo.

(iii) Only young nutritious forage with a dry matter content of 20 per cent. or more should be ensiled ; a legume-grass mixture of from 1 : 4 to 1 : 1 has distinct advantages over grass silage alone.

(iv) The chaffing and molassing at from 2 to 6 gallons per ton of green forage helps to ensure the necessary degree of acidification although neither method of processing is essential except possibly for the ensiling of protein-rich leguminous forage.

(v) The better the structure and the bigger the capacity of the silo, the less the percentage loss in ensilage ; for farm production, silos with a capacity of 8 to 10 tons or more are recommended as being more economical than smaller units.

(vi) The need for providing drainage outlets at the bottom of the silo is a debatable question; in certain conditions and for some classes of forage they do promote satisfactory ensilage but in other circumstances they may increase the percentage loss of organic matter ; too free drainage may result in mineral deficient silage.

(vii) Bulk silage was successfully made in pits without any special facilities or equipment; the choice of site and the shape of the pit to ensure effective control of both internal and external drainage are of primary significance in making good silage. After filling, the weighting and sealing over of the top of the pit are important in minimising losses in ensilage ; these losses should not exceed the 15 to 25 per cent. class by weight of ensiled material, depending on conditions.

(viii) The manufacture of silage in a circular clamp with bamboo retaining walls was not economic on account of too great a percentage spoilage through ineffectual air exclusion.

The information accruing from these preliminary experiments on the ensilage of tropical forages is not inconsiderable, but further investigations are required. In particular, accurate cost accounts will need to be kept to ascertain the total cost and the number of labour days required in manufacturing bulk silage from different forage crops, with special attention to the ensiling of a legume-grass

mixture. Digestibility trials to determine the nutritive quality of different classes of silage are also needed, especially with reference to milch cows and to the possible effect of silage on the quantity and flavour of the milk. A range of types of improvised silo suitable for peasant farmers should be tested, and their capacities and general utility defined. It is hoped to be able to undertake these supplementary investigations in the near future.

Acknowledgments

This article is an abridged report of the research work on ensilage undertaken by the four post-graduate students heading the list of references appended. To these four students, namely Messrs. Hammond, Storrar, Luscombe, and Gale, must be given all credit for a careful and painstaking series of investigations with the minimum of facilities and technical aids. Whatever value this report may have as a record of original research must be awarded to them for their attention to detail and close observation and recording of facts on a new and interesting field of investigation of some immediate practical importance.

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YEAST IN NUTRITION *

BY

F. A. WILSON, B.A., (Cantab.),
(*Nutrition Adviser to the Mauritius Government*)

Unconsciously, yeast has formed an important item in the food of many nations throughout history. Formerly in Europe, beer was a turbid drink, rich in suspended yeast, and native beers all over the world and soured milks, liberally consumed in parts of Europe and Asia, are likewise rich in it. Bread owes its structure and flavour to its activity.

Yeasts utilized in the food industries are varieties of *Saccharomyces cerevisiae* and *Torula utilis*. In general, they are characterized by a great rapidity of reproduction by simple "budding", and the ability to utilize carbohydrate and capacity of synthesizing protein from inorganic nitrogen. Some varieties of *Saccharomyces cerevisiae* produce considerable amounts of alcohol, and these are the varieties used in our distilleries. Varieties of *S. cerevisiae* used in bread-making on the other hand produce liberal amounts of carbon dioxide gas and less alcohol. *Torula utilis* produces little alcohol.

As far as nutrition is concerned, the first point which strikes attention is the conversion by yeasts of inorganic nitrogen into protein, the efficiency of which conversion is virtually the theoretical maximum obtainable. When it is remembered that protein is the most expensive essential in human nutrition, and that the efficiency of protein formation is very low in nature, this singular merit of yeast must be fully appreciated. It would appear that the biological value of yeast and flesh proteins are comparable. Table I reveals that the amino-acids, lysine and cystine usually lacking in protein of vegetable origin and usually responsible for their inferior biological value, are richly present in yeast[2].

TABLE I

Essential Amino-acid	*Amount in Dry Yeast Proteins per cent.*	*Amount in Beef Muscle Proteins per cent.*
Arginine	11.0	7.5
Histidine	3.0	1.76
Lysine	11.4	7.6
Cystine	1.16	1.55
Tryptophane ...	0.9	1.25
Tyrosine	2.5	2.2

That yeast may be classed as a complete protein food is confirmed by feeding experiments. Fed at a level of up to 6 per cent. in the diet, and comparison with milk as 100, yeast has a biological value of 91[3], which is closely similar to that of meat. In common with milk, meat, fish and egg,

* Reprinted from *International Sugar Journal*, XLVI, No. 546, 1944—Original Source: *Revue Agricole* (Mauritius), 22, No. 6, pp. 287-291.

[2]Schlottmann. *Biochem. Zeitsch.*, 291, pp. 406-14, 1937; and H. C. Sherman "Chemistry of Food and Nutrition" (Macmillan & Co.) 1938.
[3]M. Fixen. *Nutr. Abs. and Revs.*, 1935, 4.

therefore, it can be used as a supplementary food, raising the biological value of the total proteins of the dietary, and since complete protein is deficient in the local dietary, its value needs no emphasis. The value of yeast in the economics of food production is clearly emphasized when it is pointed out that one acre of land under a carbohydrate crop could yield 840 lb. of protein in the form of food yeast, but only some 70 lb. in the form of meat or milk protein[4]. Close on 50 per cent. of dried yeast is composed of protein and assuming that their proteins are of equal biological value, 1 lb. of yeast is equivalent to 2½ lb. of beef.

Merits of Yeast

But the greatest merit of yeast resides in its high content of vitamins of the B-complex[5], and grown under appropriate condition, it is, in fact, the richest natural source (Table II). Vitamins of the B-complex are generally insufficiently supplied in human dietaries, since the germ and endoderm of cereals, rich in these vitamins, are removed by refining; while other rich foods, such as meat, milk and eggs, are expensive. Relatively milk vitamin B-complex deficiency is common locally. It has been well established that vitamin B_1 is closely connected with muscular efficiency, and that a deficiency of this vitamin, even milk, predisposes to general lassitude, and an aversion to work and effort. Yeast, therefore, can play a vital rôle in maintaining the efficiency of labour under present difficult conditions.

It is also a specific in the prevention and treatment of the common tropical macrocytic anaemia. As shown by Dr. Sippe, the Acting Senior Pathologist in Mauritius, such surprising low blood counts as 650,000 red cells per c.c. can be raised to the normal 5,000,000 with a few weeks' treatment with liquid distillery yeast, and the percentage of haemoglobin may be raised from as low as 30 per cent. to the normal in the same course of time. The only other effective form of treatment is with liver extract, which is obviously beyond the reach of the majority.

[4]A. C. Thaysen. *Nature*, April 10th, 1943.
[5]*Nutr. Abs. and Revs.* 1940, 9, and other sources.

Yeast, exposed to sunlight or irradiated by ultra-violet light, develops considerable anti-rachitic properties, due to the conversion of its ergosterol into vitamin D_2. Irradiated yeast has been successfully used in curing rickets in children[6] and with milk has been claimed to be superior to cod-liver oil[7]. Similarly osteomalacia has been successfully cured in India by yeast therapy[8]. Its use as a cheap form of vitamin D in diseases of ossification and dental caries, and as a means of speeding the healing of fractures in defective calcium absorption in children &c., is indicated.

It has been used apparently successfully in diverse ailments, in gastro-intestinal constipation and skin affections, though it is not clear to what components of the yeast the good results are ascribable. There is also some exaggeration. Yeast is not a universal panacea, but rich "protective food", which owes its chief value as a complement in human dietaries so often lacking in protective essentials.

Its widespread use in appropriate forms should be ardently encouraged, and its unique value in local nutrition cannot be over-emphasized. It has been shown that the vitamin content of yeast increases markedly when the yeast cells autolyse. During autolysis, vitamin B_1 and other B-vitamins are liberated from their unphosphorylated complexes and reach a threefold increase in about 8 to 16 hours after which the concentration of vitamins diminishes, owing to bacterial destruction[9]. Obviously therefore, the vitamin content of yeast will vary widely according to the method of its manufacture.

Methods of Manufacture

Distillery yeast wastes have been utilized for years in Europe and America for cattle feeding. Owing to the high demand of protein by the pig, it has proved particularly useful in that animal feeding.

[6]Drake, Tisdall and Brown, *J. of Nutr.* 1936, 12, pp. 527-33. [7]*New England J. Med.* 1933, pp. 208, 313. [8]Wilson, *Lancet*, 1932, p. 1142.
[9]A. V. Trufanov, Kirsano V. A., *Biochimia*, 1940, 5, pp. 234-9.

TABLE II

	"Thiamin" (*Vitamin B1*) *International Units*/100 *grms.*	*"Riboflavin"* (*Vitamin B2*)* *mgrms*/100 *gms.*	*"Nicotinic Acid"* (*PP Factors*) *mgrms*/100 *gms.*
Saccharomyces Yeast (Fresh Distillery) ...	400	1.48	Up to 36.7
Saccharomyces Yeast (Autolysed & dried)	Up to 12,000	12.43	Up to 93
Saccharomyces Yeast (Bakers' compressed)	82	0.75	25.7
Torula Yeast	700	0.85	40.45
Beef Liver	100	Up to 3.0	Up to 27.5
Beef muscle	50	0.1	5.0
Pork muscle	200	0.16	3.3
Fish (fresh)	35	0.12	3.0
Egg	200	0.5	0.5-2.5
Milk	20	0.2	0.3

* The other members of the B_2 complex possibly occur in similar proportion.

The war has stirred up interest in yeast as a human food and consequently products with pleasant flavour and good keeping qualities have been developed. In such processes[5], *Torula utilis* is specially cultivated and the yeast cells separated from the culture liquid by centrifuging, washing and drying on rollers. If *Saccharomyces cerevisiae* is propagated, the chief requisite is the removal of alcohol as it is formed by blowing a stream of air through the culture medium.

The best medium is sterilized diluted molasses to which some ammonium sulphate has been added; some phosphate may also be added, but other minerals are not required. Attempting to grow yeast on synthetic media (*e.g.*, pure sugar and minerals) is uneconomic and irrational, since the vitamin content of the resulting product is low. Brown sugar can be used but is much less effective than molasses. The yeast should be allowed to decant for 24 hours undisturbed. The deposit can be sun-dried in shallow trays, in an oven at 65°C., or used directly with some sweetened water.

There is an abundant supply of distillery yeast available locally, some hundreds of tons of which precious substance are wasted annually. Considerable experience has been gained in its use in hospitals, child welfare, &c., but it could be employed on a much larger scale. Necessarily impure, its taste is somewhat sharp, but mixed with sugar it makes quite a pleasant drink. From 1 to 3 ounces are usually well tolerated. At Reunion Distillery, Mauritius, when fermentation has subsided, the yeast collected at the bottom of the vat is run off and allowed to decant in tanks for 36 hours. The supernatent liquid is discarded, and the deposit sterilized at 70°C. for 1 hour. This temperature does not destroy the bulk of the bacteria, but is a guarantee against contamination with typhoid bacilli. This autolysed, decanted yeast will keep for several days. If exposed in thin layers in the sun, the yeast so dried will keep for months. No doubt each distillery could derive its own methods, and when factories, tobacco barns and maize driers are adjoining, drying should present few difficulties.

Yeast has a great social value, and could play an important part in these difficult times with advantage both to labour and industry.

MISCELLANEOUS NOTES

Magnesium and Growth

Magnesium is necessary for other things besides flares and aeroplanes. For several years the behaviour of this element in animals has been studied at the Rowett Institute, Aberdeen, Scotland, by Duckworth, Godden and Warnock. Both in farm animals and man the amount of magnesium in the blood plasma may be suddenly reduced, the result sometimes being fatal. In severe deficiency, variation in the plasma level of magnesium is apparently paradoxical, since at first it falls sharply and then returns to almost normal levels and it is only after this return that death occurs.

It was found that during a lack of magnesium in the diet the magnesium in the skeleton is, to a large extent, liberated to meet the demands of the soft tissues for growth. An interesting conflict arises between tissues in competition for this small supply of magnesium. It seems that while the skeleton liberates magnesium in response to the demands of the growing tissues the skeleton itself is a competitor and competes with other tissues. If, in magnesium deficiency, the growth of the skeleton is simultaneously checked by withholding calcium from the animal while about the same amount of magnesium is liberated, there is no new bone-forming to claim its share. The animals then live several times as long as when the skeleton continues to increase in size.

Studies of the amounts of magnesium retained by growing children show that much more is apparently retained than the children require to meet their growth needs. It seems possible that these extra amounts really represent losses in sweat.

Poorer sections of the community seem to lack adequate amounts of magnesium for growth and maintenance. This may be an important factor in the case of heavy workers, especially miners, whose sweat losses are high. It may also be of importance in the tropics.—(*Monthly Science News*, No. 33, 1944.)

REVIEW

Lectures on the Inorganic Nutrient of Plants

By D. R. Hoagland

Published by the Chronica Botanica Company, Waltham, Mass., U.S.A., 1944, Price: four dollars ($4.00). *London, Wm. Dawson & Sons Ltd.*

This book comprises a series of seven lectures given by the Professor of Plant Nutrition of the University of California who has been investigating for many years the processes of nutrient absorption and translocation and of nutrient uptake from the soil. The lectures emphasise the part which the Californian School of plant physiology has played in the elucidation of these problems; they do not pretend to cover the subject exhaustively but rather to provide a survey of some important aspects, and in that sense the book can strongly be recommended to students of plant physiology, crop ecology and the principles of agriculture.

F.H.

COCONUT DISEASES IN JAMAICA (I)

'BRONZE LEAF WILT' AND OTHER DISEASES AFFECTING THE BUD OF COCONUTS

BY

E. B. MARTYN, B.A., A.I.C.T.A.
(*Plant Pathologist, Department of Agriculture, Jamaica*)

Introduction

The West Indian planter first became aware of the possible commercial value of the coconut during the last quarter of the nineteenth century. Pieris (21) has recently dealt with the history of coconut cultivation in Trinidad where it is apparent that the rate of expansion of the industry has been very similar to that in Jamaica. The Jamaica handbook for 1886 includes coconuts among the crops discussed under the heading 'Cultivation', advising their extension. The suggestive if not accurate figures to be found in other numbers of the same reference show an export of 2 million nuts in 1875, increasing in the next 10 years to 5 million, and later the following acreages are given under coconut cultivation in successive periods, with a maximum about 10 years ago (Fig. 1):—

	*Acres**
1891	7,816
1898	11,293
1909	11,822
1914	19,555
1915	29,731
1919	39,789
1932-33	45,880

The great majority of regular plantations are therefore not more than 30 to 40 years old. Much older palms are, however, to be seen near estate buildings, beside roads, and in other sites where they were planted in the years before the coconut was grown as a regular crop. Some of the coconut groves on the sea shore are no doubt the oldest in the island, but periodic storm damage precludes the occurrence of many palms of great age in such situations.

In comparison with other British West Indian colonies, Jamaica has on the whole been more happy in the nature of the land that offered itself for the extension of coconut planting than either Trinidad or British Guiana. The crop was often established in conjunction with bananas, becoming increasingly regarded as a form of insurance against the effects of Panama disease. This latter epidemic which in due course wiped out bananas in large areas, leaving the coconuts in pasture land, resulted in a type of agriculture which combines cattle and coconuts. This presents its own problems for which it is gradually being realised that a solution must be found. The coconuts, when established with all the attendant benefits of the care given to bananas, started life well. Now, however, the original drainage is often nearly obliterated, and its replacement is difficult on account of the cattle; the land is overgrazed and continually consolidated by the animals. Finally, more plant nutrients must be taken from the soil than are ever replaced. Partly owing to the comparatively recent establishment of large scale coconut cultivation (judged by other coconut growing countries), questions concerning optimum age, invigoration by use of manure and artificials and the possible necessity of underplanting or replanting are still to be faced seriously. Innovations, for instance, that suggest themselves as worthy of trial, are the tethering of cattle beneath coconuts or the cultivation of fodder in the coconut plantation combined with stall feeding and the subsequent return of the manure to the land, notwithstanding the possible hindrance of the fodder crop to the gathering of the coconuts.

Despite a general lack of care and cultivation the coconut in Jamaica, owing largely to the very hardy nature of the plant, does not suffer seriously from disease. The worst enemy of the crop is the periodic hurricane or near hurricane that strikes the island in varying degree and is responsible for the loss of a large number of palms, either at the time of the storm or in the ensuing months from damage received during the storm†.

Coconut diseases are rather difficult to study. Symptoms may be hard to observe in detail from the ground, and when they appear are often the results of events which took place weeks or even months before. Furthermore, investigation of the heart generally involves the death of the palm, which precludes subsequent observation and incurs significant financial loss. Early references to coconut diseases in Jamaica are made by Fawcett (13) and Earle (12). Subsequently Ashby, who was the first to study the coconut diseases of the island in any detail, was microbiologist during several successive years of storms, and therefore

* Since the above was written figures obtained in a recent census of Jamaica indicate that the total acreage under coconuts is much greater than that shown in the handbook, but as the census figures give counts of individual palms, and do not indicate acreages solely under coconuts, to which the above listed totals chiefly refer, a comparative figure indicating the position in recent years cannot be given with any accuracy.

† Since this paper was written the hurricane of Aug. 20th, 1944, struck the North Coast of Jamaica and destroyed at least 60 per cent. of the coconuts. On the areas immediately bordering the coast in Portland and St. Mary the damage in many cases approached 100 per cent., 75 per cent. of which were blown down entirely, generally breaking off at ground level, or else due to the snapping of the trunk at varying heights.

gave special attention to bud rot and the related bitten leaf diseases which become prevalent at such times.

The hardy nature of the coconut palm deserves emphasis; it does not die so long as the cabbage* and central bud remain sound. These tissues are well protected and can apparently support life on a minimum of nutrients or when supplied by a most restricted root system, so that palms are often to be seen half uprooted or growing apparently on nearly bare rock or in similar most unpromising situations and still able to produce new leaves and to cling to life. Coconuts growing under ideal conditions in Jamaica do not appear to be subject to the attack of parasitic fungi or bacteria *per se*, bud rot only occurring when accompanied by high humidity, and all other forms of disease being directly correlated with some inimical factor in the palm's environment, with the exception of bronze leaf wilt, which may affect palms apparently in full vigour and often with no very apparent contributory cause.

An entirely healthy palm growing under optimum conditions presents a crown of leaves green throughout, excepting for the oldest one, which in due course yellows and then dries up quickly and is shed by the parent plant. As environmental conditions vary from the optimum, so the palm reacts in a variety of ways, and in Jamaica it is relatively seldom that absolutely perfect palms are seen, although minor departures from perfection are often overlooked and are of no practical importance.

Departures from perfect health may take the form of drying out of the older leaf tips or colour changes in the leaves of varying degree, reduction in size of the crown, or failure to mature the fruit normally, and are always accompanied by secondary fungal and insect attack of differing intensity. The major factors affecting the health of coconuts in Jamaica, other than direct mechanical storm damage, are excessive humidity, fluctuations in soil moisture and nutrient deficiencies.

Coconut diseases have been summarised by Briton-Jones (7) and Dwyer (10). At present the nomenclature of the diseases is confusing, and what would appear to be the same disease is described under different names in various parts of the world.

* The terms "cabbage" and "crown" are used in their generally accepted sense, and as defined by Sampson (22). The term "heart" is used practically synonymously with "cabbage" except that it also includes more mature tissues, culminating in those which are beginning to turn green. The "heart leaves" are the young leaves with still unfolded pinnae but green, which are pushing up into the light, and the 'central column' refers to the young leaves in the centre of the crown which may still be not fully unfolded, and are more or less vertical, their stems forming a column around the emerging "heart" leaves, and their axillary spather not yet visible.

In dealing with the coconut diseases of Jamaica the writer proposes to treat them in four classes, though the dividing line between these cannot always be absolutely clear cut, and of course a palm may be affected by more than one disease at a time.

CLASS I.—Diseases involving the rapid death of the bud. *Bronze leaf wilt, bud rot* and *lightning strike.*

CLASS II.—Diseases affecting the emerging leaves without generally killing the bud. *Bitten leaf* and *St. Mary disease.*

CLASS III.—Diseases affecting the appearance of the whole crown, or of the outer leaves, but not immediately causing the death of the palm. *Leaf spots, die back, drought wilt, leaf break, yellowing, little leaf* and *false wilt.*

CLASS IV.—Diseases of the stem. *Stem bleeding* and *leaf scar disease.*

The present paper will only be concerned with the diseases affecting the bud of coconuts. The remaining diseases (Classes II to IV) will be discussed in another article which will also include a summary of both papers, a full list of references and a key to all diseases, based on their major visible symptoms, dealt with in both papers.

Class I.—Diseases of the Bud

This class includes two diseases, long known collectively as bud rot, but latterly distinguished and now named bud rot and bronze leaf wilt. In both cases the death of the bud is the essential symptom of the disease, and therefore the death of the palm must follow, though the final withering of the crown may be delayed. Lightning strike falls into this class as the heart and bud are killed, although general damage to the crown is usually visible at the same time.

Bronze Leaf Wilt

This is potentially the most serious disease of coconuts yet recorded in the West Indies and though pending the discovery of its exact nature it is not possible to be certain that the varying symptoms recorded in different areas originate in identical causes, the writer considers that they are closely allied and that when the solution has been found in one locality, it will enable the problem of this puzzling type of disease to be solved elsewhere. Bronze leaf is at present known only in or near the Caribbean. The name was applied by Briton-Jones (7 & 8) to the disease, formerly described as bacterial bud rot as distinct from Phytophthora bud rot, which has been responsible for the death of large numbers of coconuts in many parts of the Caribbean area. The name is not a very satisfactory one, because in the mind of the layman it is equally applicable to a number of other conditions of the coconut in which the leaves assume various shades of yellow or brown. Furthermore, the writer now considers it doubtful whether the disease is in

fact a wilt, taking that term to apply to a condition brought about by lack of water. A better name however must await the discovery of its true cause.

Over 30 years ago Johnston (17) investigated the diseases of coconuts which caused heavy losses in the Caribbean area, and considered that a similar disease occurred in other parts of the world. He however failed to distinguish Phytophthora bud rot from the disease subsequently known as bacterial bud rot. More recently Briton-Jones (7 and 8) considered this latter disease to be of non-parasitic origin, and named it bronze leaf wilt. He believed that a similar disease occurred in Ceylon, Travancore, Kenya and Mauritius. On examination, however, of the references given to support this distribution, the writer is of opinion that the wilt described in Ceylon is drought wilt, the diseases described in Mauritius are directly attributable to environment and similar to those described here under yellowing, while no symptoms of disease described in Kenya or Travancore (*cf.* Varghese (25)) agree with those of the bronze leaf wilt of the West Indies, nor do those of any of the diseases subsequently described by Dwyer (10) in New Guinea. The writer believes that bronze leaf wilt is confined to the Caribbean neighbourhood, where it occurs in Cuba, Jamaica, Trinidad, British Guiana and the Cayman Islands (17), and according to Briton-Jones (7) in St. Lucia and Tobago. Information has also recently been received of the occurrence of bronze leaf wilt among coconuts on the island of New Providence in the Bahamas. It does not occur in Puerto Rico*, and its occurrence in any of the other islands would probably have been reported if it were there, as the effects, though often confined to small areas, are devastating. There is no confirmation of its occurrence in Central America or anywhere on the coast of the mainland, where however the somewhat similar red ring disease, caused by a species of nematode, is found and may cause confusion as to the occurrence or otherwise of bronze leaf wilt.

Briton-Jones (8) and Bain (5) have described the disease in Trinidad, and consider it to be a wilt caused by unsuitable soils which either inhibit the formation of a proper root system, with consequent reduction, of the water supply to the palm in periods of dry weather, or else are liable to dry out quickly at such times. The experimental evidence on which this theory is based is somewhat scanty, not so much as to data regarding the condition of the soils, but as to the correlation between this and the symptoms shown by the palms. When the writer observed the disease in British Guiana he accepted the explanation, since the conditions surrounding the coconuts which were affected by the disease were so patently unsuited to the palm as to make the theory plausible. In Jamaica, however, for reasons to be given, the existing theory as to the cause of bronze leaf wilt will not explain the recorded and observed facts.

As regards the occurrence of the disease in Jamaica, the best references to its early history are given by Johnston (17), who visited the island in 1907 and who quotes a record of the disease at Montego Bay in 1891 by Fawcett, the latter also reporting it on the Grand Cayman in 1889 (14) and referring to a mention of what is probably the same disease there by the Marquis of Sligo in 1834.* Johnston also quotes another manuscript record by Fawcett, dated 1902, showing that the disease was well established then on the North West Coast, in St. James and Hanover. It was probably not so serious owing to the smaller number of coconuts there at that time, but it is worth noting that Johnston comments on the careful precautions taken by most planters to check the spread of bud rot diseases in Jamaica. Subsequent to Johnston's account, Ashby (2 & 4) made several references to the disease, which he distinguished from the Phytophthora bud rot of the East End of the island, and which by reason of its being confined to one area was known as West End bud rot.

In 1934, subsequent to hurricane damage in 1932 and 1933, bronze leaf wilt began to cause considerable damage in the coconut groves along the North West Coast, and the disease has continued to spread in this area during the last 10 years, until there are now only two or three coconut properties left between Montego Bay and Lances Bay (about 5 miles west of Lucea) with any appreciable number of palms. East of Montego Bay the disease has killed many palms in the neighbourhood of Salt Marsh Bay, near Falmouth, and a few cases have recently been observed between Falmouth and the St. Ann-Trelawny border. The disease is not found further than a few miles inland, but there are no regular coconut plantations away from the coast in the North West of the island. The greatest damage has been done in the almost continuous belt of coconuts that immediately bordered the coast between Montego Bay and Lances Bay.† Though forming only a very small percentage of the island's coconut industry as a whole, those plantations have in many cases been wiped out entirely.

In 1939 Bain (6), who had investigated the disease in Trinidad, was asked to visit Jamaica and report on the West End bud rot. He stated that the disease was similar to the bronze leaf

* Confirmed recently by private correspondence with the U.S. Dept. of Agriculture and the University Agricultural Experiment Station in Puerto Rico.

* There is also a record of a disease which had wiped out the coconuts along forty miles of the South West coast of Jamaica in St. Elizabeth prior to 1872, which was probably 'bronze leaf wilt'. (Report on the Condition and Progress of the Botanical Gardens, Public Plantations &c. 1871-72, and 1875-76, Vol. I, p. 342 (p.348) and Vol. II, p. 672 (p.701) in the bound typescript copies of these reports in the Department of Agriculture's library.)

† In the summer of 1944 cases began to appear in a coconut grove west of Lances Bay which had hitherto not been affected.

wilt of Trinidad, and attributable to soil conditions, and the immediate result of the report was that the cutting down and burning of diseased palms hitherto generally carried out, was largely abandoned. The writer, however, after observing the disease as it occurs here, though considering that it is probably the same as that in Trinidad, doubts the theory of a non-parasitic wilt, and until the true explanation of the disease is found, considers that it should be regarded as infectious and that diseased palms should be cut down and the crowns destroyed by fire, the latter precaution being especially advisable where new cases are observed amid otherwise healthy palms. This policy has been carried out in the areas concerned and existing legislation amended to enforce it if necessary.

The symptoms of the disease as it occurs in Jamaica are slightly variable, depending on the condition of the palm at the time it becomes affected. The first is the shedding of the young and maturing nuts, (the mature nuts may not fall until after the heart is dead), together with the blossoms on the most recently opened inflorescence, which begins to dry up. When this is seen to take place, if the most mature unopened spadix be examined (by cutting open the enclosing spathe), the terminal flowers are found to be discoloured dark brown. With the combination of these symptoms the presence of the disease may be diagnosed with certainty. In the experience of the writer, once these symptoms have appeared, recovery, which Briton-Jones claimed to be possible, cannot take place, although temporary or permanent recovery from some of the various conditions described under Class III is of course possible, and these may be affecting the palm before it succumbs to bronze leaf wilt, and may be confused with it.

Sometimes concurrent with the first fall of nuts, but as a rule somewhat later if the palm has been in full vigour, the bottom two or three leaves begin to turn yellow, and in three or four weeks the whole of the lower part of the crown assumes a deep orange yellow colour (shades 5 (butter-cup yellow) or 6 (Indian yellow) on the Horticultural Colour Chart)* indicating that changes occur in the pigments of the leaf other than a mere loss of chlorophyll. Finally the leaflets of the oldest leaves begin to turn brown, passing through a slightly varying succession of colour changes until the leaf withers and falls. It is significant however that if the palm has been in good health at the outset (and often the healthiest palms succumb first) the drying up of the leaves does not occur until the disease is well advanced, and the collapse of the outer leaves is generally the last stage of the disease and not the first as in the case of drought wilt. The rate of progress of the disease is somewhat variable, but at Haughton Court Agricultural Centre, where detailed observations were made, it was found that about three months after the *first* signs of the disease the heart leaves withered and then collapsed as a result of the base of their petioles being destroyed by the bacterial rot occurring in the cabbage. This collapse occurs about six weeks after the disease has become obvious by the marked yellowing of several lower leaves and the fall of all or the majority of the nuts. When the heart leaf collapses the central column and the half dozen or so young leaves outside it are still green. These gradually become yellow and die, and eventually all the leaves fall or are torn away by the wind, and a bare trunk is left standing.

As regards the internal symptoms, if the crown of a palm in the earliest stages of the disease is examined, the heart and growing point are found to be perfectly sound. The terminal portions of unopened inflorescences, and the flower cushions (pedicels) from which young nuts have fallen are discoloured brown, and subsequently a similar discolouration appears at the junction of the fibrous stipules and young petioles. It is these discoloured tissues in the heart that eventually become subject to a bacterial rot. Microscopic examination shows that the discolouration is probably due to an oxidase action causing the parenchymatous tissues to turn brown, but at the outset no bacteria or fungal organisms are to be found within the cells, and at first the cell walls do not break down. On exposure to air and light the white tissues of the cabbage always tend to become slightly discoloured, and on wounding they readily become subject to oxidase action. It may be noted that discolouration also takes place both in palms affected by bronze leaf wilt and sometimes in others at the junction of the 'strainers' (fibrous stipules) with the petioles of older leaves, resulting in a very sharp and clear cut margin between the dark brown tissue and the normal white surface of the inside of the base of the petiole. A like margin is to be seen also on the inside of the bases of the still green spathes. Occasionally on palms affected by bronze leaf wilt brown patches have been noticed on the white inner surface of the petiole base, which if the petioles are cut off and kept for a few days, become sunken and may ooze gum. These brown areas, apparently originating in a breakdown of the tissues, may subsequently become infected and no doubt give rise to the 'lesions' described by Johnston.

It appears therefore that in the case of bronze leaf wilt the causal factors of the disease initiate a breakdown of the tissues in the young flowering parts and developing leaves and subsequently the parts affected become a prey to the action of saprophytic bacteria, which rapidly multiply and initiate the evil smelling rot that eventually

* Issued by the British Colour Council and the Royal Horticultural Society. (The colours of the palm leaflets are of course not pure, as they are suffused with remaining traces of green, but the general effect is nearest the shades quoted.)

Members of the staff of the Imperial College of Tropical Agriculture who visited Jamaica three years ago claimed that the yellowing which accompanies the disease in Trinidad is not so intense as the orange yellow which they observed associated with bronze leaf wilt in Jamaica.

FIG. 1.—Map of Jamaica showing the principal coconut growing areas.

FIG. 2.— The result of an epidemic of bronze leaf wilt. The stumps are all those of palms killed. by the disease since 1941.

Photo by *R. Robinson*

FIG. 3.—Artificial wilt experiment

involves all of the heart. A similar rot follows the killing of the heart by *Phytophthora palmivora* in the case of bud rot. As was to be expected, all attempts at inoculation with bacteria obtained from the dying heart, both when the inoculations were made on living palms and also on healthy pieces of the "cabbage" in the laboratory, yielded negative results.

In addition to microscopic examination of the tissues of the crown, the stems of palms in early stages of the disease were sectioned and no organisms found therein, and finally a large number of roots of varying age and type, taken from similar palms in different localities, were examined. As in the case of previous investigators, no organisms were found within the stele, and although in the cortex fungal hyphae were quite commonly present, such were found in the roots also of healthy palms. The occurrence of fungi generally in the cortex of coconut roots is noted by Sampson (22). Attempts to transmit the disease by burying roots from diseased palms among those of healthy ones gave negative results.

In Jamaica, the disease is found to affect palms of all ages. It is most general on palms of about 30 to 40 years old, as these are the most numerous in the area concerned, and the onset of the disease is not generally related to the time when the palms come into full bearing, as Bain (5) suggests. It also affects much older palms where these are present. Its appearance on young palms is somewhat uncertain. Palms of about three years of age, some growing amongst cane, and some just above the shore line, in areas where bronze leaf wilt occurs, have often been observed to turn yellow, followed by the death of the heart. As no inflorescences are yet produced, the typical symptoms of the disease affecting the flower and nuts cannot be observed, but it seems reasonable to assume that such palms are suffering from bronze leaf wilt. On the other hand, in fields where bronze leaf wilt has been rampant, and which have been abandoned on this account, many young seedlings have been observed, developing from fallen and ungathered nuts, which have a yellowed appearance. These fields are used as pastures, and the presence of tall grass, together with the packing of the soil by animals, produce such unfavourable conditions as might well cause the seedlings to be yellowed. In fact, if such yellowed seedlings are transplanted to another locality without too much root damage and before the heart is affected, they will recover and develop into healthy plants. On the other hand, a number of them left *in situ* develop a heart rot and die, and it is an open question whether or not they have been affected by bronze leaf wilt or have merely died as a result of their environment.

Bronze leaf wilt in Jamaica occurs on a number of clay soils that are obviously unsuited to coconuts, but these include a clay derived from carbonaceous shale (Richmond Beds) which is exactly duplicated further East along the North Coast, near Port Maria, in an area with but little more rainfall (annual average 69″ as opposed to 61″); there coconuts may become very unhealthy and turn yellow in dry weather (chiefly as a result of soil erosion), but do *not* suffer from bronze leaf wilt. Bronze leaf wilt is also found at Lucea and elsewhere on the sandy sea shore, usually regarded as the natural ideal site for coconuts, and in one case on a small area of alluvium at the mouth of the Flint river, a deep and free draining soil on which conditions would also appear to be most suited to the palms. In fact, it is found on a variety of soils, both deep and shallow, varying from heavy clays to light sand, and derived from several geological formations. It also occurs both on coconuts interplanted with bananas and receiving ample cultivation and care as well as on those untended in pasture or on the shore. The rainfall over the area where the disease is found varies between 40 inches and 80 inches per annum and epidemics of the disease appear in different areas during wet years and years of normal and well distributed rainfall and cannot be consistently correlated with abnormal weather conditions.

In the apparent absence of causative fungi, bacteria or animal organisms, the bronze leaf wilt of coconuts must be attributed either to non-parasitic causes or to a virus. Many of the known facts about the disease however, with the exception of the above mentioned recovery, on transplanting, of seedlings doubtfully affected by it, do not tend to support the theory of a non-parasitic cause.

In the first place, the disease may kill as many as 90 per cent. of the palms in a field within two or three years. (This death rate was actually recorded in a field of 500 palms, fig. 2). Such epidemics have occurred concurrent with a variety of seasonal conditions, both wet and dry, and it is difficult to imagine how palms which have survived the varying seasons of 30 or more years in good health can suddenly die in so wholesale a manner as a result of a non-parasitic wilt.

In the second place, it seems clear that the disease is confined to the areas in and around the Caribbean aforementioned. When it occurs where coconuts are growing in plantations the records show that more often than not it becomes epidemic and it is then so striking in appearance that it could scarcely have been overlooked if it occurred in any of the other coconut growing areas of the tropics. Yet if it is due solely to soil conditions, which must cover a fairly wide range in view of the different localities where the disease occurs, it seems unlikely that these conditions should not appear elsewhere in the world, with similar results. It may also be pointed out that owing to the very varied origin of the soils on which it occurs, the suggestion which has been made that the disease is due to a soil deficiency of some kind or the presence of a toxic soil constituent is hardly valid.

Briton-Jones (8) and Bain (5) both claimed to have reproduced the symptoms of bronze leaf wilt, the former by cutting the roots of palms, the latter by raising the soil level around palms.

The writer has made a series of attempts to reproduce the disease artificially, all of them unsuccessful.

At Haughton Court, where the disease has been epidemic, the roots of healthy palms were cut in various ways. In one experiment, 4 palms were chosen, and trenches cut around each, 10 feet from the foot of the palm, to depths of 1 foot, 2 feet, 3 feet and 4 feet respectively. In another experiment trenches were cut around the base of three palms to depths of 2 feet, 3 feet and 4 feet respectively, but in this case only 3 feet from the base of the trunk. The first experiment gave entirely negative results. The latter and more drastic treatment, which was carried out in the latter part of December, after the wet season, and followed by three months of dry weather (rainfall January 3.6 inches, February 0.2 inches and March 3.42 inches) resulted in the shedding of the outer leaves in regular order, each in turn drying rapidly and then hanging down, finally to fall. By the end of March the palm within the 4-foot trench had shed 12 leaves and 3 more were hanging from the base of the crown, but the remainder of the crown remained entirely green and normal and no general shedding of nuts took place. After the onset of the summer rains no further leaves were shed, and in August this palm appeared perfectly healthy. The cutting of the lateral roots had killed the outer leaves, but the roots immediately below the base of the stem sufficed to keep the rest of the crown fully green. The symptoms produced therefore in no way resembled those of bronze leaf wilt but were more akin to those of incipient drought wilt.

In another experiment in the same locality the roots immediately below the bole of a palm were severed by tunnelling under the base of the stem, an operation which also involved cutting the lateral roots on opposite sides of the palm. No wilting had occurred within 3 months, when the palm, in common with several of its neighbours, contracted ' bronze leaf wilt '. The experiment was repeated near by, with no result after eight weeks. This experiment was also repeated with a palm on a clay soil in St. Thomas, and after three months there was no visible effect in the crown of the palm. The weather however during these latter experiments, which were carried out in the summer, was not unduly dry.

In the East end of the island, at a site near Port Morant, an experiment of a somewhat different nature was made in order to investigate the effect of artificially produced drought conditions. Coconuts in the field selected were growing under a rainfall of about 80 inches per annum, on a heavy clay, derived from marl, which is encountered at a depth of 3 to 4 feet. A trench 4 to 5 feet deep was dug round a healthy palm, so as to enclose an area 36 by 32 feet, with the palm in the centre. The palm was near the crest of a steep slope, and outlets were dug from the trench to keep it free of water. The whole surface of the enclosed area was then covered with 'paroid ' roofing, which was made to fit over the base of the palm trunk so as to be watertight and at the outside turned down and pegged over the inside of the edges of the trench (fig. 3). This roofing was subsequently covered with coconut leaves laid on it to protect it from the sun.

The roots of this palm (and of a neighbouring palm examined by cutting root exposure trenches) were chiefly confined to the top two feet of soil, tailing off in the third foot, although an occasional root could be found near the bottom of the trench. Examination of the root system nearly a year after the experiment had begun indicated that it had not appreciably deepened as a result of the digging of the trench.

It was thought that the surface soil would be rapidly exhausted of its moisture by the transpiration of the palm, and that then, owing to the ' intolerant ' nature of the subsoil (Bain (6)), the palm would at least show signs of distress. In actual fact at the time of writing, 11 months after the soil was covered, the palm looked as healthy as it had at the outset, and during a marked drought in the winter and spring (*see* rainfall, Table I) it had looked better than its neighbours, the older leaves of which yellowed slightly as a result of the dry weather. It had no doubt benefited from improved drainage and soil aeration, and the roofing had served as a mulch, giving protection from the winds of the dry weather period.

The site was chosen at the end of August, when preliminary soil samples were taken, and the cover was eventually put on during the first week in October. As the experiment proceeded samples were taken at intervals with a soil auger and their percentage moisture content determined, the figures obtained being shown in Table I.*

As is often the case in Jamaica, the soil texture was very variable, even over a small area, and the depth of ' top soil ' fluctuated considerably. Samples were taken on each occasion near to the edge of the enclosed area from a point both above and below it, and two samples were taken also inside the trench, on opposite sides of the palm, through holes cut in the covering, which was patched afterwards. Successive depths of six inches were sampled, and to obtain a representative figure and eliminate minor differences in soil texture the results shown in the table represent the means from the first and second six inches in each foot from the two samples outside the trench and from the corresponding samples taken under the cover.

Outside the trench the total percentage moisture both of the first and second fell from 33 per cent. in November to 25 per cent. in April. At the beginning of July, after 3.00 inches of rain in May and 14.00 inches in June it had risen to 29 per cent. in the first foot and 31 per cent. in the second foot. *Within the covered area,* the percentage moisture

* The writer is indebted to the soil chemist and his assistants for the various moisture determinations carried out in the course of this experiment and to the soil chemist for advice with regard to its conduct and conclusions.

Artificial Wilt Experiment

Table I.—Percentages of Total Moisture in Soil and Rainfall

Percentage of Moisture

	August	November		December		January		February		April		July	
	Samples taken before trench was dug	Outside trench	Under cover	Outside trench	Under cover	Outside trench	Under cover	Outside trench	Under cover	Outside trench	Under cover	Outside trench	Under cover
1st foot ...	28.5	32.6	25.3	32.5	28.5	30.3	22.9	27.3	23.3	25.1	23.3	29.3	21.7
2nd foot ...	28.9	32.8	28.0	34.3	26.9	31.4	26.5	30.8	25.5	24.7	25.3	31.0	24.3
3rd foot ...	...	...	...	...	...	...	...	...	...	22.8	22.9	26.0	25.1
4th foot ...	...	...	...	...	...	...	...	...	...	21.2	20.0	24.9	22.8
5th foot ...	...	...	...	...	...	...	...	...	...	22.2*	22.8*	22.5	21.0

* One sample only

Rainfall 1943-44

	Inches
August	7.01
September	4.57
October	13.88
November	8.88
December	2.20
January	2.66
February	.93
March	.97
April	1.12
May	3.00
June	13.99
July	9.43

of the first foot fell from 25.3 per cent. in November to 21.7 per cent. in July, although it fluctuated, and was not a continuous fall. This is accounted for by the very varying moisture content of the top 6 inches, which was affected by condensation of moisture under the cover, and which varied in consistency owing to the levelling of small bumps and the filling in of depressions on the surface before putting on the cover in order to fit this closely. The percentage of moisture of the second foot, however, showed a steady drop from 28 per cent. in November to 24.3 per cent. in July, and if the percentage moisture figures obtained at each sampling are plotted against the times at which the samples were taken, a very regular descending curve is obtained, with an indication of flattening out towards the end.

In April a longer auger was employed than before, and it was found that the third, fourth and fifth feet of soil had a moisture content of between 23 per cent. and 20 per cent. both inside and outside the enclosure, which showed an increase by 2 per cent.—3 per cent. in the third and fourth feet in the July samples, both inside and outside, the fifth foot however showing little change. The apparent inconsistency of the 3rd and 4th foot samples is however probably due to chance, according to whether the auger struck a point where the underlying marl was higher or lower.

Bain (5) reckoned the percentage available moisture of the Trinidad soils as percentage total moisture minus the hygroscopic coefficient, and on this basis showed some very low values for available moisture in the dry season, sometimes approaching zero. The hygroscopic coefficient of the soil in this experiment varied between 5 and 8, so that the comparable figure to Bain's for percentage available moisture would never have been less than 12 per cent.

Figures given by Patel (19) indicate that a coconut transpires from 6-16 gallons (62-163 lb.) of water per day. Assuming arbitrarily that the palm in this experiment transpired an average of 10 gallons per day, then from the time the soil was covered in October, 1943, until the last soil samples were taken in July, 1944, a period of 9 months, say 270 days, elapsed, in which 27,000 lb. of water would have been transpired. Taking the generally accepted figure that 1 acre of clay soil, 6 inches deep, weighs 2,000,000 lb., and applying this to the block of soil cut off by the trench (36 by 32 by 4.5 cubic feet), the weight of soil in the block can be calculated as 476,100 lb. (though with the increased weight of the more compact subsoil it would actually be more). The total weight of water assumed to be transpired therefore represents 5.67 per cent. of the total soil weight in the block cut off (and a transpiration rate of 16 gallons per day would represent

9 per cent. of it). These figures can only be taken as an indication, and to investigate the matter properly it would be necessary to know the actual amount of water transpired by the palm. It is however worthy of remark that the drop in the percentage water content of the top two feet of soil under the cover during the course of the experiment is in the neighbourhood of 5 per cent. (*cf.* Table I).

It would be of interest to repeat this experiment, keeping direct rainfall away from the roots of the palm by means of raised roofing, which would, however, have to cover a larger area. In this manner the secondary factors introduced by the mulching effect of the roof, and possibly by condensation of moisture under it, would largely be done away with, and if studies of rates of transpiration and the wilting co-efficient of the soil were made concurrently, it would be possible to obtain more detailed information as to the relative parts played by sub-soil water and direct rainfall in maintaining palms on clay soils in a fully vigorous condition.

The conclusion from these experiments is that no drought, even the most prolonged ever known in the history of Jamaica, would kill palms on clay soils by wilting, and rapid wilting and death from drought are impossible on such soils. Furthermore, it seems to be indicated that after an initial fall in soil moisture, the moisture content tends to remain constant, presumably owing to upward movement of moisture from the lower layers of the soil, and this minimum moisture content appears to be well above the wilting point of a coconut and the coefficient of wilting of these clay soils. This latter factor, however, requires investigation with regard to coconut soils generally.

To investigate the effect of raising the soil level around the base of a coconut, a palm was chosen at Haughton Court, and soil of the same nature as that in which it was growing was placed around it and rammed, so that the soil level was raised to a height of 2 feet over a circle 6 yards in diameter, with the palm in the centre. The palm so treated showed no unusual symptoms for 11 weeks, it then began to shed nuts and subsequently developed bronze leaf wilt, but as a number of neighbouring palms developed the disease at the same time, it may be assumed that its occurrence in the treated palm was natural. Bain (5) claimed that as a result of a similar treatment in Trinidad palms showed symptoms similar to bronze leaf wilt ' within a few weeks '. The experiment was repeated at Haughton Court, and after eight weeks the palm showed no unusual symptoms. An attempt to replicate this experiment elsewhere was nullified by hurricane damage.

Other experiments carried out included the injection of palm stems, through auger borings, with water, and with a solution of salts of magnesium, cobalt, manganese, zinc and iron from vessels suitably placed. Salts of copper, sodium, magnesium, zinc and manganese, in muslin bags, were also introduced into the hearts of palms. As none of these experiments showed any positive effect in checking the disease they are not described in detail.

The attempts described above to reproduce bronze leaf wilt symptoms by upsetting the normal water and air relationships of the root system suggest that although wilt symptoms can be artificially induced by drastic means, the symptoms of the disease are not obtained, nor can any form of wilt be expected to produce the rapid succession of symptoms culminating in the death of the heart, which typify bronze leaf wilt.

The whole appearance of bronze leaf wilt in the field is suggestive of an infectious disease. As no visible organism is to be found present in the earliest stages, and as the symptoms do not appear compatible with a non-parasitic disease, a disease of a virus nature must be considered as a possibility. The first and most obvious objection to this hypothesis however is that if a virus disease had been present in one part of the island for at least 50 years, it would presumably by now be far more widespread than it is. The only way to overcome this objection is to postulate the existence of a vector not generally airborne, and severely limited in its distribution by environmental factors. The symptoms are not those generally associated with virus diseases, and differ from such recorded diseases of coconuts elsewhere as are tentatively ascribed to viruses, notably some obscure diseases described by Dwyer (10) which are possibly of virus origin and a number of diseases involving reduction in the size of the crown, references to which are listed at the end of the section dealing with pencil point. It is worth noting, however, that the general, although not universal, spread of the disease in the direction of the prevailing wind, which has been noted by a number of observers and is especially remarked by planters, is compatible with an air-borne vector, as is also the marked increase of the disease after seasons in which violent storms occurred.

Experiments were carried out to see if the disease could be artificially sap transmitted, material from the stem of diseased palms being introduced in distilled water into stems of healthy palms by means of auger borings, crushed material from inflorescences in the early stages of the disease being similarly introduced into the heart of healthy palms, and the ' milk ' from green nuts on palms in an early stage of the disease being introduced into green nuts of healthy palms. All these yielded negative results. In addition, mature nuts were obtained from diseased trees which on germination gave rise to healthy seedlings, though it is possible that the disease, even if of a virus nature, might not be seed-borne.

It is thus apparent that the true cause of 'bronze leaf wilt of coconuts' still remains to be found. The main features of the disease are its alarmingly epidemic nature where it does occur, and its confinement in many cases to relatively small districts in places where coconuts are cultivated.

Though at first glance it appears to be correlated with soil conditions, the very varied soil types on which it occurs invalidate this hypothesis, and if it be indeed non-parasitic, its appearance elsewhere in the tropics might be expected to occur. No causal organism has been found to account for it, nor has a disease of a virus nature been proved responsible. Moreover, if it were infectious, its distribution might be expected to be more widespread in the islands, &c., where it is found, owing to its very rapid localised spread. The contradictory nature of the facts so far discovered about the disease indicate that more intensive investigation is required to solve the problem, the solution of which, however, would probably throw light on a number of obscure diseases of coconuts in other parts of the world.

Bud-Rot

This disease, due to destruction of the bud by *Phytophthora palmivora* Butler, has been reported from most parts of the world where coconuts are grown. It was first recognised and described in Jamaica by Ashby (2 and 4) and the symptoms in general agree with those described elsewhere. In normal years it does not cause any serious loss, but it can attack palms of all ages and is endemic in the Eastern parishes of the island where the rainfall generally averages over 100 inches per annum. Its occurrence is definitely correlated with unduly humid conditions, and the disease becomes prominent, according to Ashby, from two to seven (generally four to five) months after hurricanes or other storms accompanied by heavy rains, when serious losses from the disease always occur.* This, as Ashby suggests, is probably owing to mechanical storm damage giving unusual opportunities for infection by material of the fungus that is being widely dispersed under the prevailing circumstances. The increased humidity at the same time favours the growth of the fungus. This correlation of the disease with wet weather is also reported by Tucker (24) in the neighbouring island of Puerto Rico, and is generally recognised elsewhere.

* *e.g.* After the 1917 hurricane 80,000 damaged and diseased palms were cut down and burnt in Eastern St. Thomas and Portland.

Unless planters are on the look-out for bud-rot its occurrence in normal years may escape their notice until the disease is well advanced, and if the death of the heart leaves is overlooked the disease may not be noticed until the rot has spread to cause a sudden rapid collapse of the outer leaves. The varying symptoms and rate of progress of the disease are described by Ashby.

As a control measure, diseased palms are cut down when they are noted and the crown split up and if possible burnt, to remove a source of infection. Neighbouring palms are treated by pouring a cigarette tin full of a 1 : 3 : 5 mixture of copper sulphate, slaked lime and salt into the heart, which fungicide is subsequently more evenly distributed among the young tissues as it is dissolved by rain water. Unfortunately, however, on the occasion of storm damage, when the most serious harm is done, it is not always practical to apply prophylactic measures on a large scale before infection has taken place, and the value of routine prophylactic treatment is by no means certain, as many of the palms may be destroyed by a hurricane in any case and the accompanying torrential rains largely wash away the fungicide just at the time when it is most needed. It is important, however, to apply the treatment immediately after a storm to all palms in the wind swept area not blown down or irreparably damaged.

Lightning Strike

Lightning damage in Jamaica is not as serious as in Malaya, New Guinea or other areas where electrical storms are commoner and more violent. It is, however, of quite general occurrence, and palms struck and killed exhibit symptoms similar to those described elsewhere, namely a collapsed crown and exudation from the stem, which is very soon attacked by boring insects. The tips of the leaves of palms adjoining those that are actually killed are also often scorched. Palms killed by lightning should be cut out and others planted in their place.

(*To be concluded*)

NITROGEN FIXATION WITH MOLASSES

According to a paper by S. B. Lee and R. H. Burris published in *Industrial & Engineering Chemistry*, Vol. 35, No. 3, pp. 354-357, it has been known for some time that a sugar solution, such as molasses, could be used to grow yeast by adding to the molasses some inorganic nitrogen in the form of ammonium sulphate. Since sugars of various kinds can now be obtained cheaply in large amounts, this fact has been accepted as a convenient means of obtaining yeast as a proteinous foodstuff rich in vitamins. Preparation of food yeast by this method requires a certain amount of added nitrogen, amounting to about 145 lbs. of ammonium sulphate per 100 lbs. of sugar employed, or 29 parts of ammonium sulphate on 100 parts of dry yeast manufactured. The authors of this paper have found that a proteinous food similar to yeast can be prepared from molasses without addition of any outside nitrogen. Instead of yeast they use another micro-organism, *Azotobacter vinelandii* which, unlike yeast, can take its nitrogen from the air. The cell paste obtained in this way is comparable in nutritive value to yeast both as to protein content and vitamin content. The process has not yet passed the experimental stage but it appears to have interesting prospects.—(*Sugar*, Vol. 39, No. 10, 1944.)

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Formation of Humus from Plant Residues and Manures by Animalcules

Each genus of the smaller soil fauna seems to perform a specific function in the transformation of organic matter in the soil. The most numerous of the lesser fauna are the nematodes of which 200 and more are often found in 100 gm. of soil. Most of these are harmless to living plants but play an important rôle in the decomposition of cellulosic plant residues. Different kinds of earthworms behave differently. *Octolasium* spp. feed off humified material which is thereby destroyed; *Lumbricus* spp. feed off fresh plant residues which are excreted as humus intimately mixed with mineral matter. There is evidence that diplopods, slugs, land lice, midges, *Collembola*, larvae and caterpillars take an active part in the humification of different organic materials. Attempts were made to determine the amounts of humic matter (insoluble in acetyl bromide) formed per day by different animals from different raw materials. In 100 days an earthworm produced 0.53 gm. of humus from black-alder leaf residues, and a louse 0.09 gm. The corresponding figures for beech leaves were 0.24 and 0.02 gm. Earthworms appeared to be the most active humus formers. Though the amount of humification per insect or animal is small the total numbers of the soil fauna are often very high and may account for a considerable proportion of the humus produced. The animal population of dung heaps and composts is usually much higher than that of soils, and varies roughly with the cellulose content. It is, however, not yet possible to state whether the interaction of small animals in the rotting process is the most desirable.—(*Soils and Fertilizers*, Vol. VII, No. 3.)

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Manurial and Cultural Experiments on Paddy in Ceylon

The results of several manurial and cultural experiments are discussed in the 1942 *Annual Report of the Director of Agriculture*, Ceylon. It was found that an application of 1 cwt. per acre of Nicifos to paddy a month after sowing, or half that amount before sowing and a month after, is more effective than application of the full hundredweight before sowing. A long-range trial on rice at Bathalagoda has demonstrated the benefit of cultivating with the plough as compared with buffalo-mudding and mamoty cultivation. It was also found that the operation of harrowing liberates nutrients and should be beneficial to the crop, especially in soils which have received inadequate preliminary cultivation.

* * *

Glycyrrhizin

This is probably the sweetest substance which occurs naturally, being about 50 times sweeter than sucrose. It is the sweet principal of liquorice (*Glycyrrhiza glabra*), an account of the history, cultivation, chemistry and commerce of which was recently given by P. A. Housman in the 26th Streatfield Lecture to the Royal Institute of Chemistry. Spanish liquorice root contains 6-8 per cent. of it, and that from the Near East about 10-14, but the former variety commands nearly twice the price of the latter, due therefore not to its sweetness, but to its superior flavour. By far the greatest part of the world's supply of liquorice extract is used, however, not in confectionery as might be supposed, but in tobacco products, for the prevention of drying-out. (*The International Sugar Journal*, Vol. XLVI, No. 552.)

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Leaf Composition in Relation to the Mineral Nutrition of Tung Trees

An article in *Soil Science*, 1944, 57: 281-91, presents data on the nutritional requirements of the tung tree as a result of leaf analysis. As a preliminary step, the composition of the leaf, as influenced by date of sampling, position of leaf on shoot, fruiting and non-fruiting terminals on the same trees, soil conditions and fertilizer treatment, was studied in three tung orchards in Florida and Louisiana. Samples were analysed at three dates to determine the content and seasonal trends of nitrogen, phosphorus, potassium, calcium, magnesium, manganese, iron and ash. The results are tabulated. Soil conditions were found to have a greater influence on leaf composition than any of the other factors considered.

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A New Method for Observation of Micro-Organisms in the Soil in vivo

The Strugger method with acridine orange for live staining was used for direct fluorescence observation of live soil bacteria. The soil is screened and shaken up in 1 : 5000 dilution of acridine orange (tapwater); part of the suspension is observed. All dead matter appears red to red brown; live bacteria are green. The bulk of the organisms is tightly held by the humus and does not separate by shaking; only a few dead bacteria are found. The number of live bacteria of various kinds varies from 100 million per g. of soil for autumn or winter in poor soils to 1/1½ thousand millions in rich compost.—(*Soils and Fertilizers*, Vol. VII, No. 3, 1944.)

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